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<u>Author(s)</u> Katherine Ray		<u>Collaborating Institution</u>			
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<u>Title</u> SUPERCONDUCTING MAGNET PROGRAM / LARP QXF GENERAL MQXFA INTEGRATION AND LOADING WI					

MQXFA Integration and Loading Work Instructions (WI)

Windchill Unique ID: **SU-1011-5637**

Rev: **C**

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Prepared by

Checked by

Katherine Ray

Work Instructions Originator

Approved by

Daniel Cheng

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Revision History

Revision	Issued	Changes
A	1-28-2020	Original Issue, based on SU-1008-8070 Rev B and SU-1008-8068 Rev B.
B	2-28-2020	Update figures 16-18, 21, 24, 27, add instructions for bagging & flowing N2, adjust axial rod positioning, reorder steps in section 4 & 5
C	5-21-2020	Add VP for pressure hold check, general loading process

Purpose

The purpose of this Working Instruction is to describe the process of inserting the Coil Pack into the Shell-Yoke Assembly, then loading the magnet axially and azimuthally. This document supersedes the earlier separate WIs ("Magnet Fiducial WI" SU-1008-8070, and "Axial End Load Structure WI" SU-1008-8068). This process is performed after the Shell-Yoke Subassembly, Coil Pack Subassembly and Axial Rods Instrumented work instructions have been completed and before the Splice Box work instructions.

At the end of this work instruction is an attached Verification Signoff Sheet (VSS) which is a mandatory quality tracking document required by project guidelines; a separate, serialized VSS will be completed and saved for each magnet assembly.

Scope

This work instruction covers Coil Pack insertion, axial rod and end plate assembly, bladder operations, and axial loading. This work instruction will detail the individual steps required for each step along the way, as well as "Verification Points" that require a signoff action.

Definitions

- Verification Signoff Sheet = VSS
- Verification Point = VP
- Lead End/Return End (LE/RE) – the lead end is the end where the leads, or wires attach to the magnet. The return end is the opposite end of the magnet.

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Reference Documents

- SU-1008-2169 – MQXFA Shell Yoke Instructions
- SU-1008-8074 – MQXFA Coil Pack Subassembly Work Instructions
- SU-1010-2018 – MQXFA Magnetic Measurements Work Instructions
- SU-1008-8069 – Axial Rods Instrumented Work Instructions
- SU-1008-8067 – Splice Box Work Instructions

Tools Required

Calibrated Tools:

- Strain gauge reading set-up
- High pressure system
- Hydraulic pump system

Non Calibrated Tools:

- Araldite AV/HV 1580
- Molykote
- Jacks & blocks
- Metric Allen wrench set
- Stainless steel shims
- Survey tooling blocks
- Coil stoppers
- 27K646 – MQXFA Coilpack Roller Spine Assy (Skate wheels & end plates)
- 27K918 – MQXFA Winch Assy
- Crane
- Magnetic lifting handles
- Clamps
- 27K631 – High Pressure Bladder (16x)
- 27K697 – Bladder Pull-shim (16x)
- 27K698 – Bladder slot shims (+010, +015, +020)

Hardware Required

Fabricated Parts & Hardware:

Part #	Description	Req'd
SU-1010-4968	Master Alignment Key	8
27K710	Alignment Key Shims	A/R
SU-1011-1665	Load Keys	16
SU-1011-1668		16
27K708	Load Key Shim Sets	A/R
27L213	Master Key half, bladder cutout	8
27L214	Master Key half, no bladder cutout	8
SU-1010-9472	Full Length Shell-Yoke Assembly	1
SU-1010-8225	Coil Pack Subassembly	1
27K564	Axial Endplate, RE	1
27K557	Axial Endplate, LE	1
27K657	Axial Bullet, 95 mm long	A/R
27L338	Axial Bullet, 75 mm long	24
27K963	Axial Rods Instrumented	4
27H634	Wire Guide Assembly	8
27K655	Coil End Pusher Plate	8
27K656	Axial SST Pusher Plate	8
SU-1010-2824	Cable Support	4

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Work Instructions

1 Overview

1. Enter the following information on the Verification Signoff Sheet:
 - a. Magnet Serial number
 - b. Start date
 - c. Serial numbers of all component parts to be used in the assembly

2 Integration Table Preparation

2. Assemble the two "Bottom"/"C" Master Key packages with the nominal shim stack and place them into the shell-yoke subassembly.

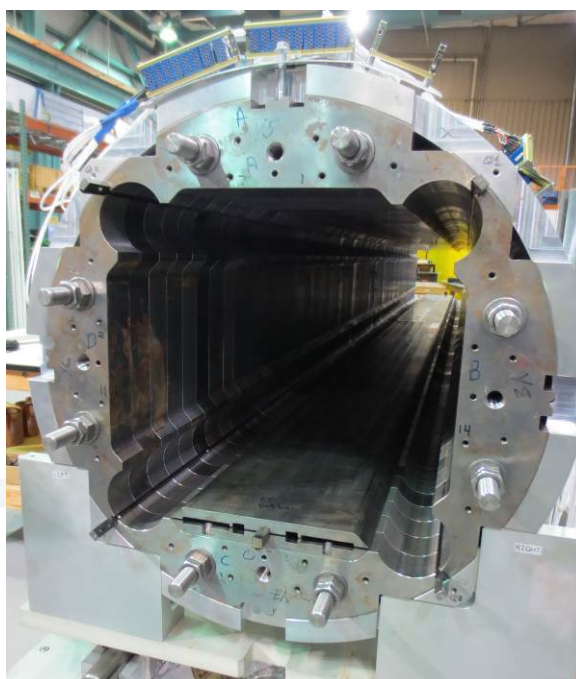


Figure 1: Master Key packages assembled in the bottom of the shell-yoke subassembly

3. Ensure the LE/RE is oriented correctly
4. Record the pairing information of each master key package, and the shims used in the stacks in the VSS.

VERIFICATION POINT 1

5. Insert the Cooling Hole Pigtail connector into the Sector 1 cooling hole of the magnet. Ensure then RE/LE orientation is correct. Tie the connector in place only at the ends, must be removable.
6. Use the coil-pack assembly table's hydraulic lifters to raise the coil pack.

7. Place the 2 skate wheel fixture on either side of the coil pack. Attach the 2 end plate fixtures to the skate wheels

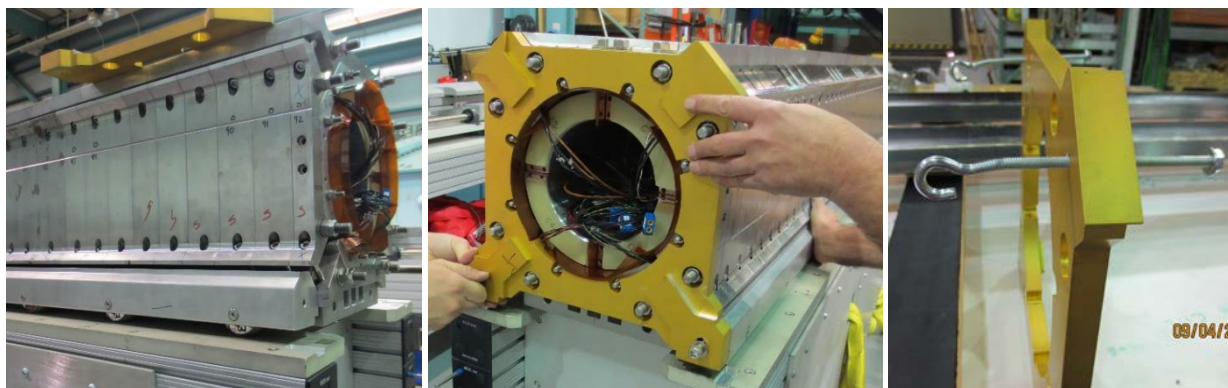


Figure 2: Skate wheels under coil pack (left), end plate attached to skate wheels (center) hooks to attach top of end plate (right)

8. Remove the M6 screws that attached loadpads to collars

VERIFICATION POINT 2

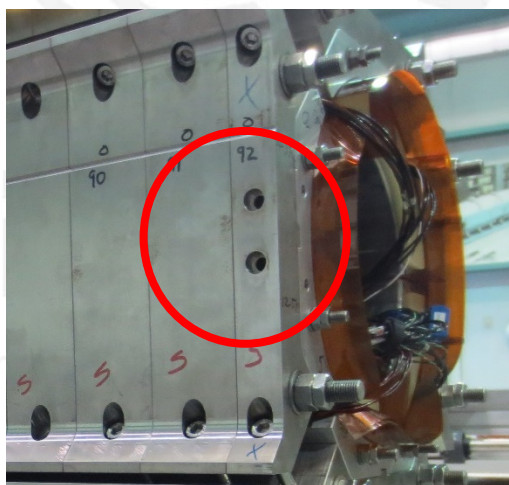


Figure 3: Example M6 screw location, 5 locations per side

9. Release the assembly table's hydraulic lifters to lower the coil pack onto the skates.
10. Strap the coil pack to the coil pack integration table.



Figure 4: Moving the coil pack integration table. Note coil pack strapped to table (left), 2 pins align the coil pack integration table to the shell-yoke assembly table (right).

11. Align the integration tables for both the Full Length Shell-Yoke Subassembly and the Coil Pack. Strap the tables together.



Figure 5: Strap the two tables together

12. Make sure the back end of the coil pack is aligned with the shell-yoke assembly. If it is crooked, it will not slide in smoothly.

3 Coil Pack Insertion

13. Add stopper for the sliders on the rails of the magnet integration table to prevent the shell-yoke subassembly from sliding during the insertion.



Figure 6: Stopper on the rail of the magnet integration table

14. Add stopper for the coil pack on the RE of the shell-yoke subassembly.

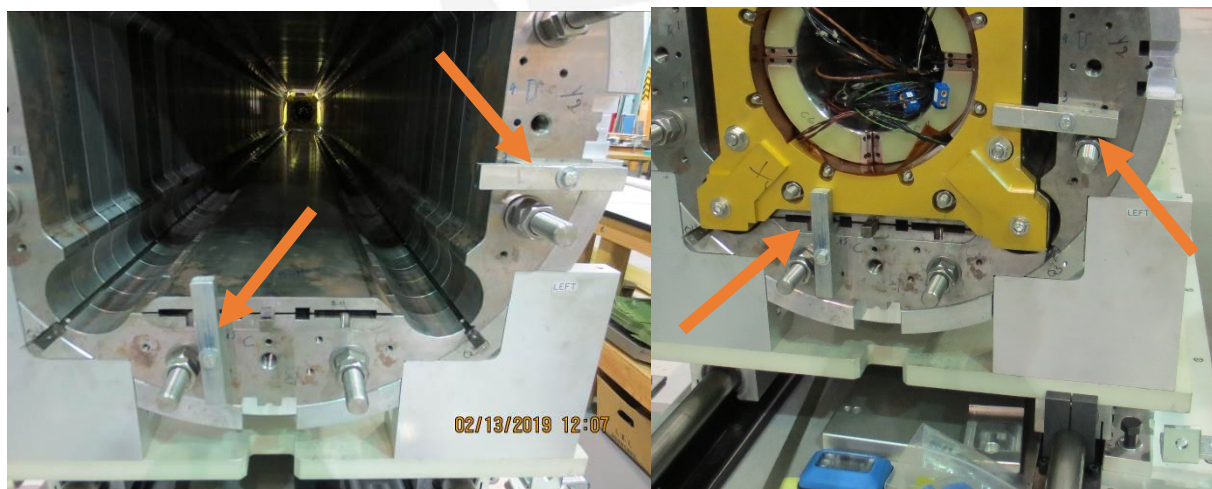


Figure 7: Stoppers for the coil pack on the RE side of the shell-yoke assembly

15. Adjust height of coil pack integration table to ensure the coil pack can be inserted.
16. Carefully and slowly insert the Coil Pack Subassembly into the shell-yoke assembly by pushing on the lead end of the Coil Pack while having an assistant watch for any snags.



Figure 8: Insert coil pack

17. Verification of proper depth alignment.

18. Remove the end plates.

4 Master Key Package Installation

19. Have Cognizant Engineer provide the pairing information for the rest of the Master Key packages, and assemble each pair with the nominal shim stack. Record the pairing information in the VSS.

VERIFICATION POINT 3

20. Place each Master Key Package in the specified quadrant. Bladder cutout should point radially outward.

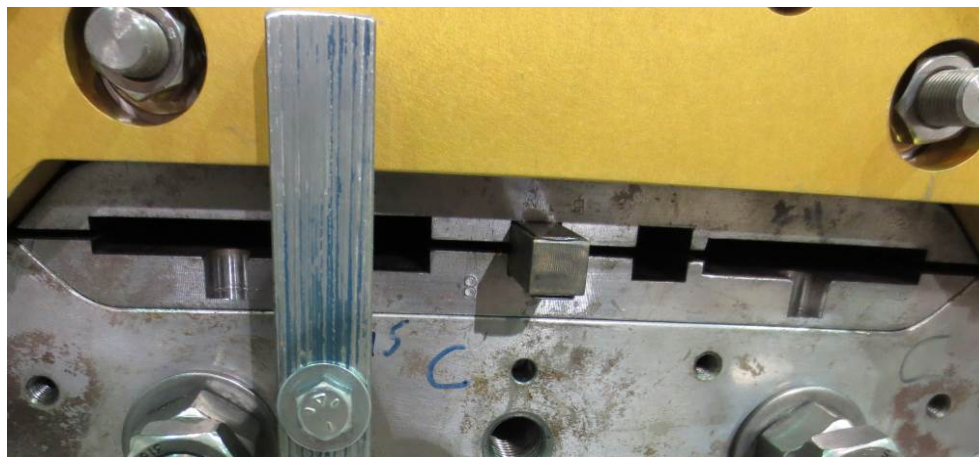


Figure 9: Bladder cutouts point radially outward



Figure 10: Handling master key packages: glue shim to alignment key (left), use magnetic handles to lift (center), clamp two master key halves together and lift with a crane (right)

21. Verify the load key thicknesses are in tolerance.

VERIFICATION POINT 4

5 Axial End Load Structure Assembly

22. Prepare the LE and RE of the magnet coils by attaching G11 pushers (27K655) with double sided tape and/or Araldite AV/HV 1580. Be careful to leave clearances for the wires coming off the RE end shoes, and any other voltage tap wires coming off the Lead End.

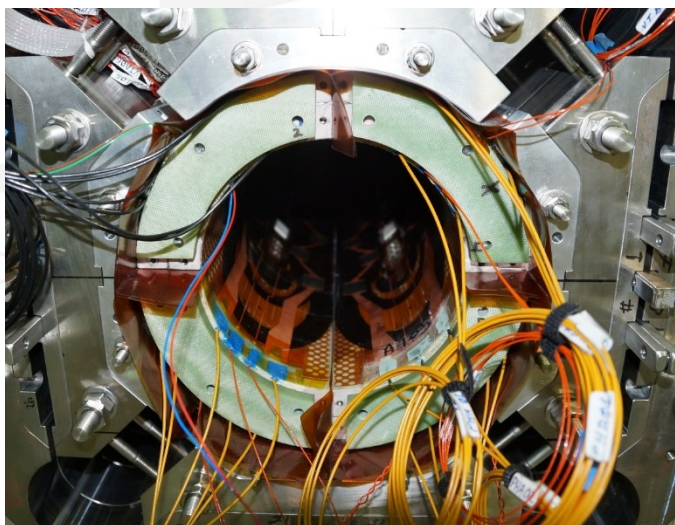


Figure 11: G11 pushers installed.

23. Route the inner layer wires through the wire guide assembly (Figure 12) to ensure they don't get pinched. Screw the 3 pieces of the assembly together.



Figure 12: Wire guides

24. Tape the wires to the outside of the shell to keep them out of the way.

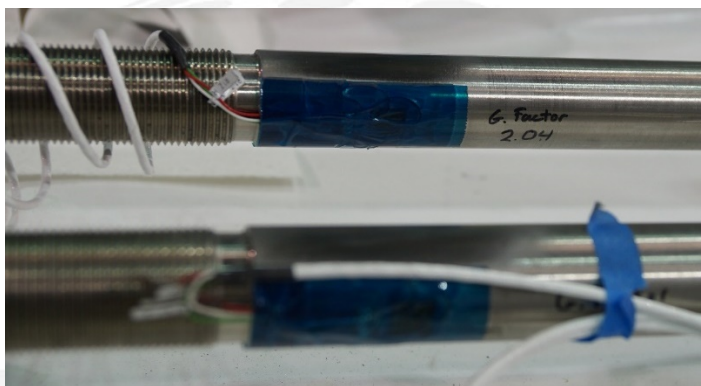


Figure 13: Axial rods with strain gauges attached.

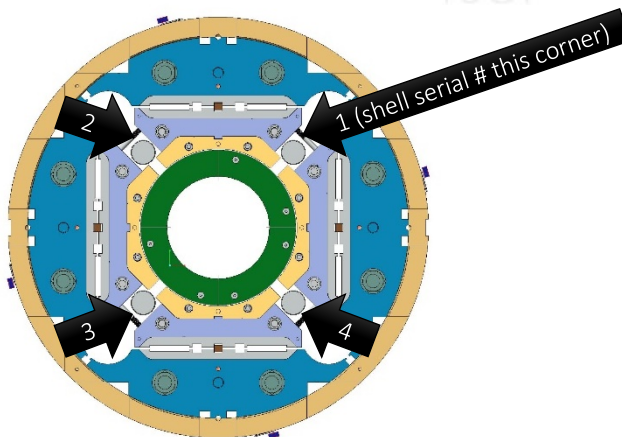


Figure 14: Numbering convention of rod locations. View from the lead end.

25. Install each axial rod. Protect the Strain Gauges and wire during installation. The LE is the side with the square cut-out in the end of the rod. Record which rod goes in which location (locations numbered as in Figure 14).

VERIFICATION POINT 5

26. Add the 75 mm bullets to the LE axial end plates and the RE axial end plates (Figure 15). They should be flush with the side facing the coils.

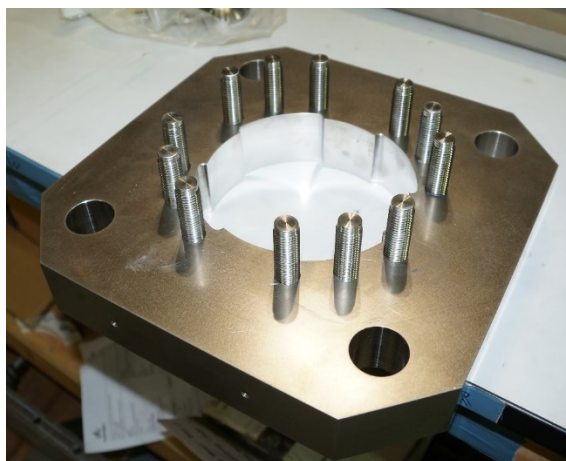


Figure 15: Bullets in RE axial end plate.

27. Fit the cable supports around the leads.

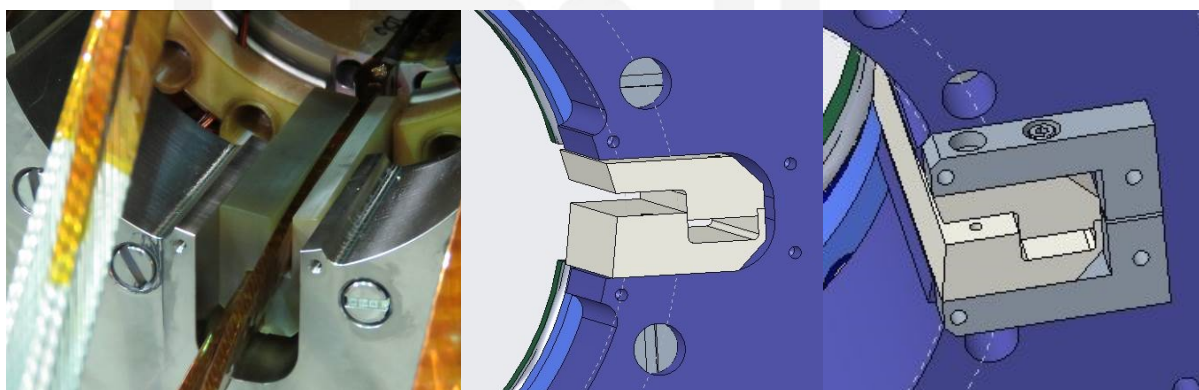


Figure 16: Cable support assembly

28. Using a crane, position the LE axial end plate (27K557). Insert the cable supports into the slots in the end plate.

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29. Screw axial rods into LE axial end plate.

- a. **Take care with the instrumentation wiring.**
- b. Have someone at the return end checking wiring there
- c. Screw until flush, then ensure that the mark at the end of the rod is oriented to point radially outward. (Should correspond with one of the 4 strain gauges pointing radially outward)

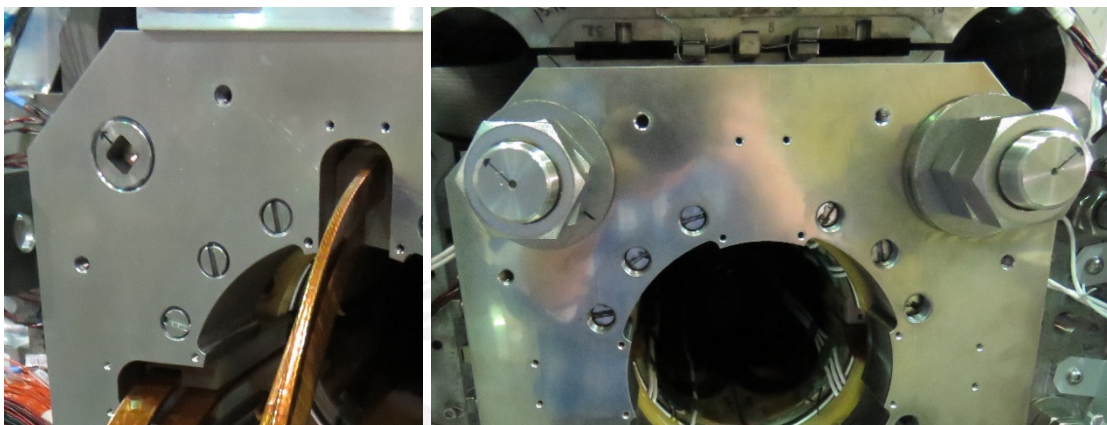


Figure 17: Mark on the rods point radially outward

30. Fit the bullets into the wire guide holes, and screw until the bullet-wire guide alignment is solid, but do not screw all the way yet.
31. Push the rod-plate assembly towards the return end. Use four 35 mm gauge blocks between the end plate and loadpads to set the spacing and use ½" square rods to ensure the plate is centered and square with the coil pack.
32. Attach the cable supports to the end plate.
33. Set the plate on jacks to support it.

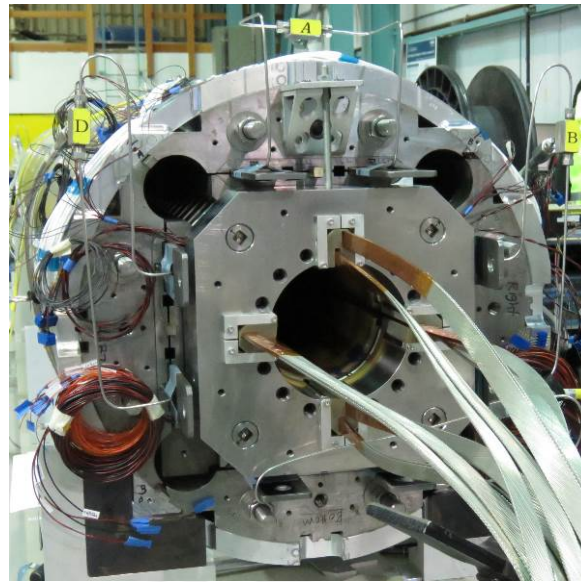


Figure 18: LE Axial end plate in place, cable supports attached.

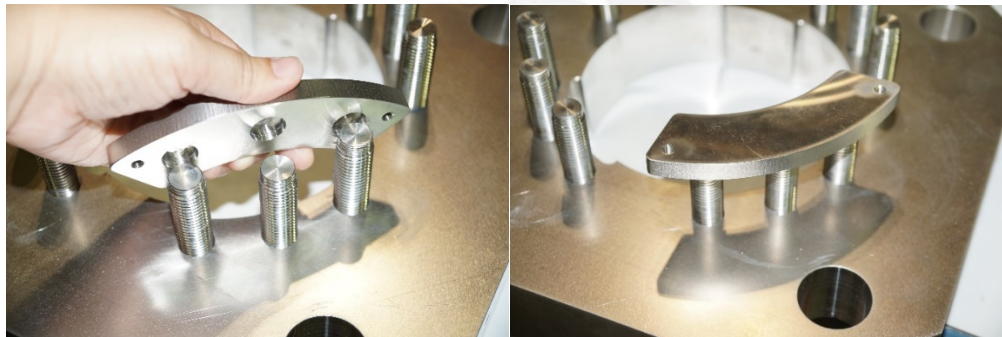


Figure 19: How the stainless steel pusher fits with the bullets

34. Use a mirror to verify that no wires are pinched inside the bore and/or behind the axial end plate. Take photographs.

VERIFICATION POINT 6

35. Using a crane, position the RE axial end plate (27K564) into place on the rods. Fit the bullets into the wire guide holes and screw in until the bullet-wire guide alignment is solid. Use temporary jacks and blocks to hold the plate in place.
36. Add the spherical washers over each rod and one nut per rod.

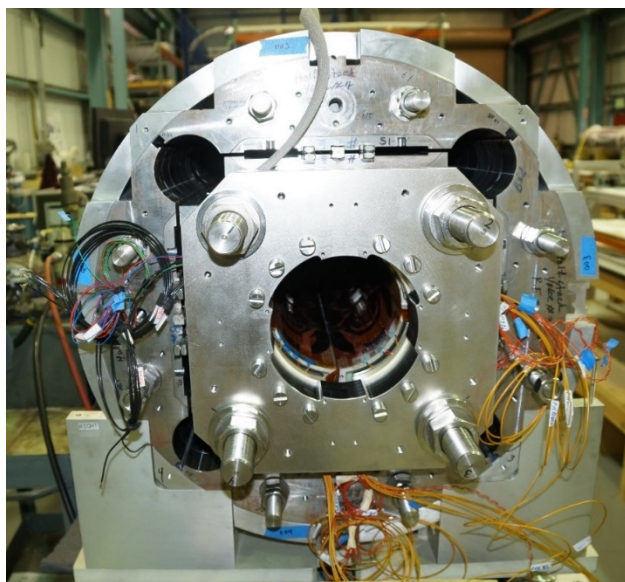


Figure 20: RE axial end plate in place

37. Center and square up the RE axial end plate. Use four 35 mm gauge blocks between the end plate and loadpads to set the spacing and use ½" square rods to ensure the plate is centered and square with the coil pack.
38. Tighten all bullets (lead end and return end) until they contact the stainless steel pusher plate (SU-1009-8201).
39. Install bracket on top of LE and RE end plates to keep in place during loading

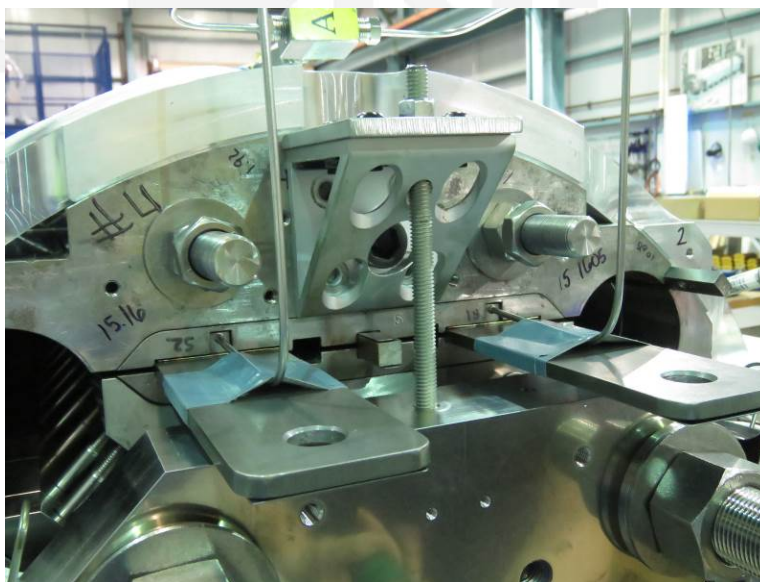


Figure 21: Bracket to keep end plates in place

40. Assemble the bladders with bladder pull keys. Mark pull keys to know when to stop inserting them, so they are centered – 6.125" from the end.

41. Add as thick a shim stack as possible between the pull key and master key
 - a. The shim stack must be of equal thickness at all 16 bladder locations.
 - b. This will minimize the amount of bladder expansion
 - c. Start with 20 mil, check if you can add more
42. Mount the rod extensions for the axial load rig onto the RE.

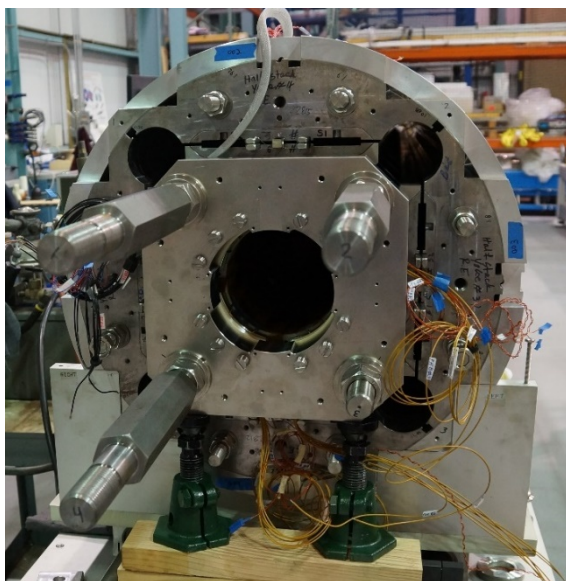


Figure 22: Three rod extensions mounted

43. Install the round filler block between the load plate and the axial end plate.

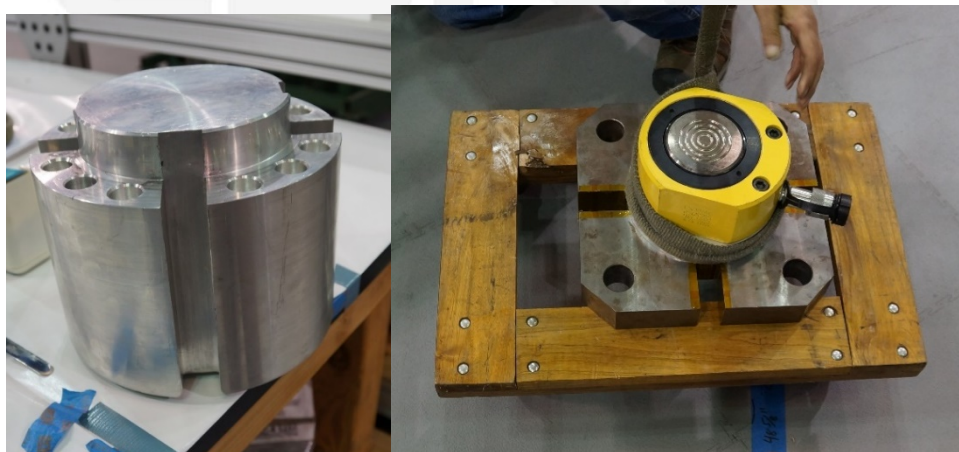


Figure 23: Round filler block (left) hydraulic cylinder (right)

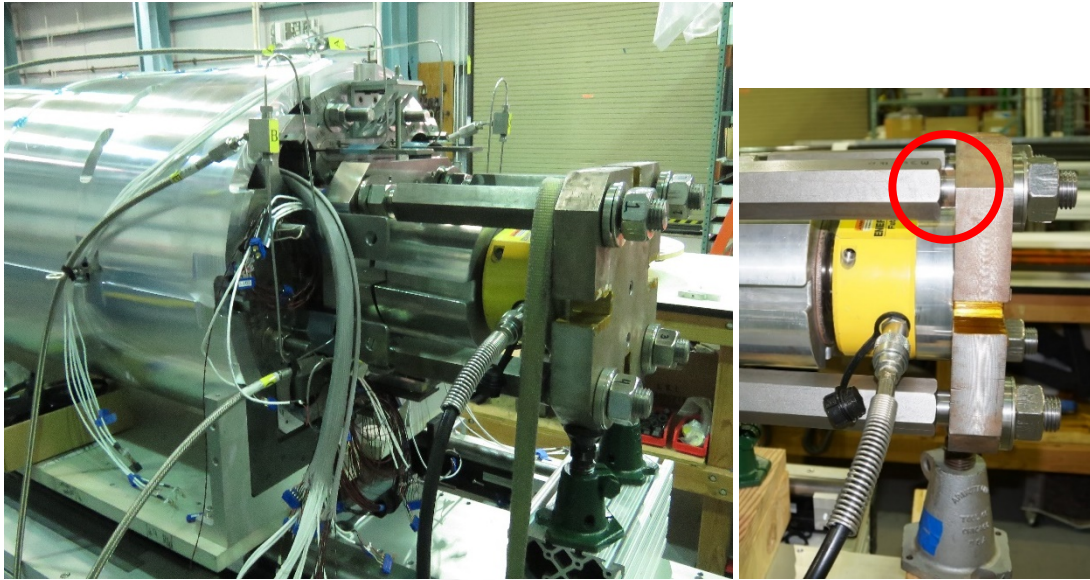


Figure 24: Hydraulic cylinder attached to RE axial end plate. Leave at least $\frac{1}{4}$ " between step and backing plate, aim for a plate to plate distance of 11".

44. Place the end plate and secure with nuts. Aim for a plate to plate distance of 11".
45. Add the hydraulic cylinder. (Note, the cylinder has a stroke of 16 mm and the axial rods will stretch approximately 7 mm during the axial loading process – leave a minimum of $\frac{1}{4}$ " between the step in the rod and the backing plate).
46. Have Cognizant engineer connect the strain gauge system to the axial rod strain gauges.

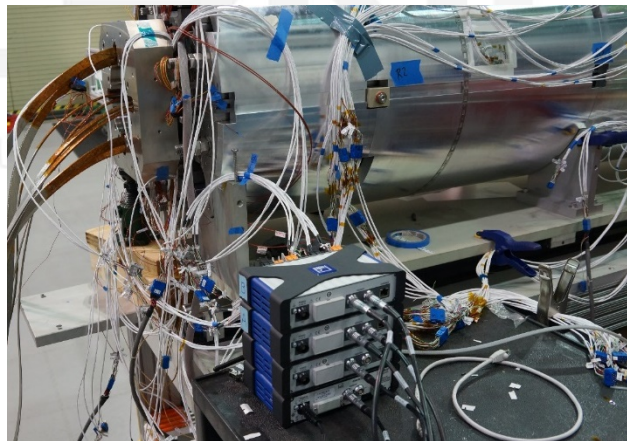


Figure 25: Strain gauge system attached

6 Loading Operations



CAUTION: Hydraulic system parts and connections can contain high pressures which, if suddenly and unexpectedly released, can cause serious injury.

Only trained personnel may operate the high pressure system. Wear face shields when at the ends of the magnet, safety glasses while at the sides of the magnet, and rope off area.

47. Order N₂ in case the magnet needs to be flushed after operations.
48. Test the valves on the high pressure system – close the valves, pressurize to at least 5000 psi (no higher than 7000 psi), check that there are no leaks.

VERIFICATION POINT 7

49. Connect all the bladders to the high pressure system. Check the water level to make sure the reservoir is fully filled.
50. Ensure that the water lines do not block the skate wheels from being removed.



Figure 26: Filling the reservoir

51. Have Cognizant Engineer connect the strain gauge system to the shell strain gauges. Protect the instrumentation connections from potential water leaks on bladders.
52. If any strain gauge broke during axial rod installation, mount dial indicators on all 4 rod extensions, touching the face of the axial end plate. (If more than 1 strain gauge broke, consult cognizant engineer).
53. Release any ratchet tie down straps on the shell.

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6.1 Initial Axial Load

54. During the initial axial load, aim to bring the 4 rods to a microstrain of 50 $\mu\text{m}/\text{m}$ using the hydraulic cylinder.
55. Step up slowly in increments of 100-500 psi
 - a. Adjust the nuts at the end of the extension rods to ensure you're pulling evenly
 - b. Tighten the nuts on the RE axial end plate until they are finger-tight, then loosen the ones that are under greater strain by 1 flat (1/6 of a turn) or a fraction of a flat to keep the level of strain even
 - c. Drop the pressure down to 0 psi and check the effect
56. When the average microstrain reaches approximately 50 $\mu\text{m}/\text{m}$, move on to bladder operations.

6.2 Initial Azimuthal Load

57. The aim of the initial azimuthal loading steps are to insert half the final shim stack into the load keys (~20-30 mils)
58. Bleed the system.
 - a. Open 1 valve at a time to let the water get to the bladder connection
 - b. Tighten the connection when the water reaches it
59. Prepare the stainless steel keys with dry moly lubricant.
60. Pump and purge all four quadrants at once five times up to 500 psi. Watch and fix leaks if there are any.

TIMING NOTE: This operation can take ~15 minutes the first time it is performed

General Azimuthal Loading Process

- Pre-assemble at least a quadrant's worth of shim step load keys
- Engineer declares target pressure
- Pressure System Operator (PSO) goes to the pressure
- Wait 5-10 seconds. Pressure should remain stable. If not, remove pressure and troubleshoot
- When PSO says pressure is okay, Engineer checks with Technicians at both ends of the magnet
- Technicians check that keys are loose, give verbal confirmation when they are ready. If not, Engineer chooses a higher pressure, begins process again.
- Remove keys, add shims, replace keys. If new thickness does not fit, replace with old thickness. DO NOT increase pressure in the middle of this step.
- Technicians report when they are done

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- Engineer asks PSO to remove pressure
- PSO removes pressure and reports to Engineer
- Record data, repeat process

61. Pressurize the bladders on all quadrants to 1500 psi to check if 5 mil shims can be inserted.

- a. If not, release the pressure to zero without shims
- b. If 5 mil shims can be inserted, have all quadrants shimmed to 5 mil, then release the pressure to zero.

62. Have Cognizant Engineer monitor the strain gauge readings.

63. Repeat pressurizing the bladders on all quadrants to no higher than 4000 psi and try to have all quadrants shimmed to 20-30 mil (or number specified by Cognizant Engineer). Step up slowly in increments of 500 psi. Make sure the strain readings are within the designed allowable ranges, otherwise pause the pressurizing operation.

64. Release pressure after each operation and have Cognizant Engineer record the strain gauge readings at each step.

6.3 Axial Load to the Halfway point

65. Continue axial loading, aiming for half the final microstrain (approx.. 460 $\mu\text{m}/\text{m}$). Minimize the spread between all readings.

66. Step up slowly in increments of 100-500 psi

- a. Adjust the nuts at the end of the extension rods to ensure you're pulling evenly
- b. Tighten the nuts on the RE axial end plate until they are finger-tight, then loosen the ones that are under greater strain by 1 flat (1/6 of a turn) or a fraction of a flat to keep the level of strain even
- c. Drop the pressure down to 0 psi and check the effect

67. When the microstrain is at halfway to nominal, move on to bladder operations.

6.4 Full Azimuthal Load

68. Have Cognizant Engineer provide the final target for the bladder operation step. (approximately ~45 mil of shims, 78 MPa pressure on the coil).

69. At this point, you may not be able to pressurize all 4 quadrants.

70. Pressurize the bladders in two opposite quadrants each time to continue the loading process. Step up the shims slowly in increments of 2 or 3 mils.

71. Drop pressure to zero after each operation, and have Cognizant Engineer record the strain gauge readings.

72. Check the yoke gap keys at each step, remove gap keys if they are loose enough.

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73. Begin checking to see if the load is off the skate wheels, and if they can be removed.
74. Check the target to ensure if any of the target criteria are met.
75. Once the bladder operation is complete, enter the following information to the VSS:
 - a. Final shim thickness achieved in all quadrants.
 - b. Peak bladder pressure during the operations.
 - c. Failed bladder location if there are any
 - d. Complete date and sign off

VERIFICATION POINT 8

6.5 Full Axial Load

76. Ensure you know what the final microstrain should be (~960 $\mu\text{m}/\text{m}$). Aim to minimize the difference between the rod readings.
77. Step up slowly in increments of 100-500 psi
 - a. Adjust the nuts at the end of the extension rods to ensure you're pulling evenly
 - b. Tighten the nuts on the RE axial end plate until they are finger-tight, then loosen the ones that are under greater strain by 1 flat (1/6 of a turn) or a fraction of a flat to keep the level of strain even
 - c. Drop the pressure down to 0 psi and check the effect
78. Have the cognizant engineer sign off when the magnet has been fully preloaded.

VERIFICATION POINT 9

6.6 Remove Loading Equipment

79. Remove the axial loading fixturing
80. Add a jam nut to each rod on the Return End. (Torque 20 ft-lbs)
81. Remove the skate wheels (from step 7) from the structure if they have not already been removed.
82. Remove the gap keys if they have not already been removed.
83. Use 27K918 Winch Assy to pull out the pull shims.
84. Remove the bladders.
85. Mark the bladders (sharpie) with:
 - a. Which magnet they were used on
 - b. Their location during that pressurization
 - c. Highest pressure seen

86. If there have been any bladder leaks, bag the ends of the magnet and flush with N2 for at least 24 hours before doing any electrical testing.

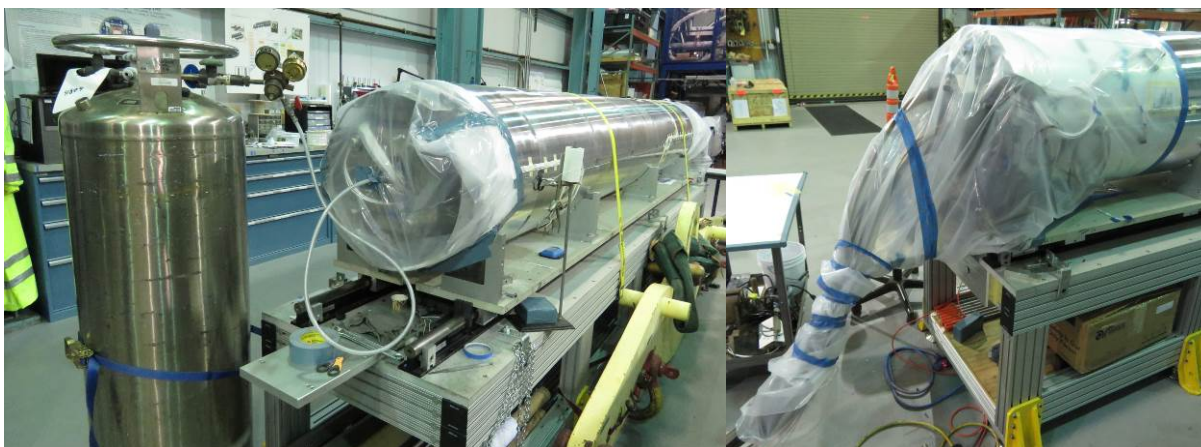


Figure 27: Bag ends of magnet and flow nitrogen

7 Completion

87. Perform the Electrical QA tests. Attach results and/or upload them to Windchill.

VERIFICATION POINT 10

88. Enter the completion date and temperature in the Verification Signoff Sheet.

89. Have Verification Signoff Sheet signed and dated by Quality Assurance.

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Verification Signoff Sheet

EACH MECHANICAL SYSTEM IS REQUIRED TO HAVE A COMPLETED VERIFICATION SHEET.

VERIFICATION MUST BE DONE BY AN ENTITY OTHER THAN THE ASSEMBLY TECHNICIAN.

SERIAL NUMBER:	
ASSEMBLY START DATE:	ASSEMBLY COMPLETION DATE:
COMPLETE ASSEMBLY VERIFIED BY (Sign and Date):	

PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)
SU-1010-9472	Shell-Yoke Subassembly	1	(LE short shell) SU-1010-1072
SU-1010-8225	Coil Pack Subassembly	1	(LE top loadpad) 27L250
27K564	Axial Endplate, RE	1	27K564
27K557	Axial Endplate, LE	1	27K557
27K963	Axial Rods Instrumented	4	See Below, Verification Point 5



VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)																								
1		Bottom quadrant Master Key Pairing: <table><tr><td colspan="2">LE</td><td colspan="2">RE</td></tr><tr><td>Cut out</td><td>Solid</td><td>Cut out</td><td>Solid</td></tr></table>	LE		RE		Cut out	Solid	Cut out	Solid	N/A																	
LE		RE																										
Cut out	Solid	Cut out	Solid																									
2		Verify M6 screws between loadpads & collars are removed (all 30)	N/A																									
3		Right quadrant (LE view) Master Key Pairing: <table><tr><td colspan="2">LE</td><td colspan="2">RE</td></tr><tr><td>Cut out</td><td>Solid</td><td>Cut out</td><td>Solid</td></tr></table> Left quadrant (LE view) Master Key Pairing: <table><tr><td colspan="2">LE</td><td colspan="2">RE</td></tr><tr><td>Cut out</td><td>Solid</td><td>Cut out</td><td>Solid</td></tr></table> Top quadrant Master Key Pairing: <table><tr><td colspan="2">LE</td><td colspan="2">RE</td></tr><tr><td>Cut out</td><td>Solid</td><td>Cut out</td><td>Solid</td></tr></table>	LE		RE		Cut out	Solid	Cut out	Solid	LE		RE		Cut out	Solid	Cut out	Solid	LE		RE		Cut out	Solid	Cut out	Solid	N/A	
LE		RE																										
Cut out	Solid	Cut out	Solid																									
LE		RE																										
Cut out	Solid	Cut out	Solid																									
LE		RE																										
Cut out	Solid	Cut out	Solid																									



VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION		CAL INFO	VERIFICATION BY (Sign & Date)
4		All Load Key Thicknesses within 6.35±0.03mm (6.32-6.38mm), measure 5 locations, record in table below		N/A	
5		Location	Rod Serial Number	N/A	
		1			
		2			
		3			
		4			
6		No pinched wires. Attach photographs.		N/A	
7		Pressure hold check complete		N/A	
8		Final Shim thickness: Peak Bladder Pressure: Failed Bladder Location (or N/A): Date:		N/A	



VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION			CAL INFO	VERIFICATION BY (Sign & Date)
		Location	Final Preload	Pressure Achieved		
9		1			N/A	
		2				
		3				
		4				
10		Electrical QA Report Attached			N/A	

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Load Key Thicknesses

	Meas. Loc. 1	Meas. Loc. 2	Meas. Loc. 3	Meas. Loc. 4	Meas. Loc. 5
LE - Top 1					
LE - Top 2					
LE - Left 1					
LE - Left 2					
LE - Bottom 1					
LE - Bottom 2					
LE - Right 1					
LE - Right 2					
RE - Top 1					
RE - Top 2					
RE - Left 1					
RE - Left 2					
RE - Bottom 1					
RE - Bottom 2					
RE - Right 1					
RE - Right 2					
Spare					
Spare					